International Journal of Disaster Risk Reduction 32 (2018) 4–10

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

journal homepage: www.elsevier.com/locate/ijdrr

Translating the Sendai Framework into action: The EU approach to ecosystem-based disaster risk reduction

Nicolas Faivre[a,*], Alessandra Sgobbi[b], Sander Happaerts[c], Julie Raynal[d], Laura Schmidt[e]

[a] European Commission, Directorate-General Research & Innovation (DG RTD), Directorate - Climate Action and Resource Efficiency, Unit - Sustainable Management of Natural Resources, Belgium

[b] European Commission, Directorate-General for Climate Action (DG CLIMA), Directorate - International & Mainstreaming, Unit - Adaptation, Belgium

[c] European Commission, Directorate-General for Regional and Urban Policy (DG REGIO), Directorate - Smart and Sustainable Growth and Programme Implementation IV, Unit - Smart and Sustainable Growth, Belgium

[d] European Commission, Directorate-General for Environment (DG ENV), Directorate -Natural Capital, Unit - Biodiversity, Belgium

[e] European Commission, Directorate-General European Civil Protection and Humanitarian Aid Operations (DG ECHO), Directorate Emergency Management, Unit Disaster Risk Reduction, European Voluntary Humanitarian Corps, Belgium

ARTICLE INFO

Keywords:
Disaster risk management
Ecosystem-based approaches
European Union
Sendai framework
Climate change adaptation
Resilient societies
Ecosystem services
Nature-based solutions
Green infrastructure

ABSTRACT

The strong linkages between disaster risk reduction and the environment are well-acknowledged, and are magnified by the impacts of climate change on the severity and frequency of environmental disasters (landslides, floods, storm surges, forest fires, etc). Most of the time, ecosystems themselves can offer sustainable solutions for the reduction of disaster risks and the severity of their impacts, while adapting to global changes. Nature-Based Solutions, Ecosystem-based Adaptation, Green Infrastructure and Natural Water Retention Measures are examples of ecosystem-based initiatives that have been promoted by the European Commission to address a variety of policy goals. In this context, ecosystem-based approaches for Disaster Risk Reduction aim at improving the condition and resilience of ecosystems in urban, rural and wilderness areas and as such, contribute to implementing the new Sendai Framework for Disaster Risk Reduction 2015–2030, while also contributing to achieving other policy objectives - from biodiversity conservation to climate change adaptation.

The European Commission has also been actively engaging the research community to better address disaster risk management knowledge and technology gaps through its Research and Innovation strategy and Framework Programmes, notably Horizon 2020. Research has shown that ecosystem-based approaches are often cost-effective and provide a wide range of co-benefits for local and regional economies, social cohesion and the broader environment. Fostering green growth through promoting risk-proofed investments and building the capacity of local, regional and national authorities and communities is a priority of the EU Action Plan for Disaster Risk Reduction, which sets the basis for a disaster-risk-informed approach to policy making at EU level.

1. Introduction

Disasters affected close to 1.7 billion people worldwide in the last decade according to the United Nations Office for Disaster Risk Reduction [41]. Whether of natural or man-made origin, disasters are becoming increasingly extreme and complex, exacerbated by the impacts of climate change, urbanisation and changing land-use patterns. Reported economic losses caused by weather and climate-related extremes amounted to over 400 billion Euros in Europe over the period 1980–2013 [25]. Flooding affects more people worldwide than any other hazard and is the main risk faced by European emergency management authorities. In Europe, at least 14 million people are living in flood-prone areas according to a medium scenario with a 100-year return period [24]. The EU has made significant progress in establishing legal frameworks for disaster risk reduction as well as strengthening existing frameworks to remain effective with respect to emerging hazards. Although the risk awareness levels in the EU are generally high, the National Risk Assessments carried out by Member States underline the need to further reduce and prevent vulnerabilities and strengthen disaster management cooperation [9]. The 2015 UN World Conference on Disaster Risk Reduction and its associated Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR; [41]) form an ambitious appeal for cooperation to achieve substantial results globally. In recent years, the Union Civil Protection Mechanism has strengthened European cooperation and solidarity across the disaster risk management cycle, from prevention to preparedness and recovery. In light of the

* Correspondence to: European Commission, Office: CDMA 03/070, B-1049 Brussels, Belgium.
E-mail address: nicolas.faivre@ec.europa.eu (N. Faivre).

https://doi.org/10.1016/j.ijdrr.2017.12.015
Received 2 June 2017; Received in revised form 19 December 2017; Accepted 26 December 2017
Available online 27 December 2017
2212-4209/ © 2018 Elsevier Ltd. All rights reserved.

more complex and frequent natural disasters that have seriously affected many European countries over recent years, the European Commission revealed ambitious plans to upgrade the Civil Protection Mechanism. A key part of the proposal is the creation of rescEU, a reserve of civil protection capabilities at European level to complement national assets in order to support countries hit by disasters such as floods, forest fires, earthquakes and epidemics [20]. All these aspects will be promoted through an EU Civil Protection Knowledge Network.

Science and knowledge are important contributors to European actions, from preventive measures such as risk assessments to the running of the Emergency Response Coordination Centre for disaster preparedness and response. The European Commission has actively supported various scientific research programmes that have contributed to a better understanding of risks in all its dimensions. Multinational interdisciplinary research in the field of natural and technological disasters has led to the development of innovative tools and methodologies to forecast and monitor man-made and physical hazards [31]. On the other hand, research efforts in support of risk management and crisis management have greatly contributed to the preparedness for, and the response to major crises and helped reduce the toll on human lives and economic assets.

The complex interplay between natural or human-induced phenomena that increase disaster risk and natural capital depletion or degradation has led to considering a more systemic perspective on how to address simultaneously climate change effects, ecosystem functioning, human health and socio-economic security [23,39]. Ecosystem-based approaches have emerged as a cost-effective instrument to confront these concerns across all sectors of society and as such, differs from traditional approaches that address single concerns e.g. species, sectors or activities [39]. Ecosystem-based disaster-risk reduction (Eco-DRR) can be defined as the 'sustainable management, conservation and restoration of ecosystems to reduce disaster risk, with the aim to achieve sustainable and resilient development' [6]. This approach is being supported in the international policy arena through several multilateral agreements such as the SFDRR [40]. The European Union and its Member States have produced a substantial body of legislation to help protecting, conserving and enhancing ecosystems and their services (e.g., Biodiversity Strategy to 2020, Blueprint to Safeguard Europe's Water Resources, EU Strategy on adaptation to climate change, Roadmap to a Resource Efficient Europe).

The European Commission is actively engaged in supporting investments in ecosystem-based management for adaptation and disaster risk reduction, through mainstreaming the ecosystem-based approach concept in its sectoral policies. The following highlights the integrated approach of EU policies to Disaster Risk Reduction and describes how ecosystem-based approaches, in particular Eco-DRR, are promoted in this context. Recent research developments and initiatives are presented to highlight the potential, enabling factors and limitations of Eco-DRR to address multiple societal challenges.

2. EU legislation and policy frameworks in support of disaster risk reduction

2.1. An integrated approach to disaster risk reduction

Over the last decade, the Commission has developed a comprehensive and integrated approach to disaster risk reduction as part of its commitment to sustainable development, both within the EU and in developing countries. The Communication on "Next steps for a sustainable European future" [16] refers to this integrated approach. Communications on an "EU Strategy for Supporting Disaster Risk Reduction in Developing Countries" [7], a "Community Approach on the Prevention of Natural and Man-Made Disasters" [8], and an "EU Approach to Resilience" [10] underline the important contribution DRR and resilience make to other EU policies and international agreements. These Communications also draw lessons from the extensive experience of responding to recent disaster-related crises across the globe and outline the concrete measures that the European Union is taking to help vulnerable populations managing future risks. Reflecting this approach also inside the European Union, the 2013 Decision on a Union Civil Protection Mechanism includes a chapter on disaster prevention and earmarks a share of the civil protection budget for prevention activities. The Sendai Framework for Disaster Risk Reduction 2015–2030 was signed by all EU countries and endorsed by the European Commission [41]. The SFDRR commits countries to substantially reduce disaster risk and losses by 2030. It offers an opportunity to advance disaster risk reduction in Europe across multiple internal and external policy areas by making all policies risk-informed. As such, it marks a crucial shift from managing disasters to managing risk and establishes resilience-building as a common denominator with the 2030 Agenda for Sustainable Development. In addition, it promotes cross-border cooperation to enable policy and planning for the implementation of ecosystem-based approaches that consider shared natural resources, such as river basins and coastlines, and integrate resilience and disaster risk management concepts.

The EU Action Plan on the Sendai Framework for Disaster Risk Reduction [17] represents an important cross-cutting contribution to many EU policies to developing a risk informed approach. It covers both developing countries and EU Member States, and sets out a coherent agenda for enhancing risk prevention, building the resilience of societies and leveraging investments through different EU policies, notably development, humanitarian aid, civil protection cooperation, but also critical infrastructure protection, flood risk management, water and biodiversity protection, global health, and food and nutrition. The Action Plan seeks to implement the SFDRR within the EU to help reinforce ecosystem and societal resilience to current and emerging risks by creating an all-of-society approach to disaster risk management. In this respect it contributes to foster innovation by building risk knowledge in all EU policies and contributes to sustainable growth and job creation by promoting risk-informed investments. Within the EU, the regulations governing the European Structural and Investment (ESI) Funds, which account for almost half of the EU budget, stipulate that disaster resilience must be horizontally promoted [27]. This is seen as a way to integrate the sustainable development principle and it follows the environmental integration principle of the EU Treaty [26].

2.2. Integrating disaster risk reduction in other EU policies and strategies

Beyond specific disaster risk management policies and strategies, ecosystem-based approaches to DRR are mainstreamed in several policy areas, climate change adaptation, and development and humanitarian aid, and also supported by nature-based tools and strategies such as green infrastructure.

The link between DRR and climate change adaptation (CCA) is an ongoing scientific challenge [1] and is already addressed in several EU policy frameworks. The 2013 EU strategy on adaptation to climate change [11,12] calls for the implementation of adaptation policies in synergy and full coordination with disaster risk reduction.

The link between the DRR agenda and other sectoral policies (e.g. environment and biodiversity, humanitarian and development aid, energy, health, urban policy, security) is also gaining prominence, with climate change and natural disasters acting as threat multipliers that can exacerbate the impacts of environmental degradation, undermine livelihoods opportunities, and force people to relocate. In EU external policies such as humanitarian aid and development, there is a strong emphasis on making communities resilient to shocks, thereby reducing the need for post-disaster intervention. Equally, within the EU, a range of policies including the Floods Directive, the Biodiversity Strategy and the EU Green Infrastructure Strategy recognise the central role of ecosystems for reducing natural hazards. Adopted in April 2017, the EU Action Plan for nature, people and the economy includes the development of guidance for further supporting the deployment of EU-level

Green Infrastructure projects towards reaching the EU's biodiversity targets for 2020. These policies and actions promote an integrated approach to resilience based on the delivery of essential ecosystem services, and therefore contribute to strengthening the DRR agenda.

3. Ecosystem-based approaches in the EU policy framework for DRR

The European Commission promotes ecosystem-based approaches that contribute to the conservation, enhancement and restoration of biodiversity, ecosystems and ecosystems services in urban, rural, coastal and natural areas. These initiatives constitute a positive and cost-efficient way of supporting disaster risk reduction and adaptation to climate change, while often providing significant co-benefits in terms of climate change mitigation or human health, safety and well-being.

3.1. Synergies and differences between ecosystem-based approaches

Ecosystem-based Adaptation (EbA), Natural Water Retention Measures (NWRM), Ecosystem-based Disaster-Risk Reduction, Green Infrastructure and Nature-Based Solutions (NBS) are closely related approaches and which can be complementary in providing a range of co-benefits. But each of them addresses social, economic and environmental challenges from a distinct perspective, whether the main concern is biodiversity conservation, climate change adaptation, disaster risk reduction, economic development or human health and well-being. As a result, they may generate different outcomes in respect of economic gains and effectiveness. For instance EbA and Eco-DRR are sometimes applied in areas to maximize co-benefits for their conservation priorities and can miss significant opportunities in promoting agroecology and/or agroforestry.

Ecosystem-based disaster risk reduction refers to the use of ecosystem-based approaches in order to reduce disaster risk [6]. The Sendai Framework for Disaster Risk Reduction encourages the use of such approaches in order to build resilience and reduce disaster risk.

Ecosystem-based Adaptation is defined as "the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change" [43]. Ecosystem-based approaches are one of the possible elements of an adaptation strategy, and address the links between climate change, biodiversity, ecosystem services and the sustainable management of natural resources, and have the potential to achieve multiple benefits beyond climate change – ranging from biodiversity conservation to livelihood opportunities, health and recreational benefits.

Nature-Based Solutions for urban and territorial resilience use nature's complexity, power, features and processes to address such challenges in a systemic manner. NBS are solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience [28]. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.

Green Infrastructure 'is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services [32]'. The rationale is that biodiversity-rich natural areas, such as woodland, ponds or wild flower meadows may be used for multiple purposes and generate various benefits while maintaining ecosystem functions. Examples include the restoration of floodplain, wetlands and forests that increase habitats connectivity and carbon sequestration while enhancing natural flood defences. Green Infrastructure is therefore considered as a cost-efficient tool to mitigate and adapt to the adverse effects of climate change. The EU Green Infrastructure Strategy promotes the development of Green Infrastructure throughout the EU at transnational, national, regional and local levels, through its integration into relevant policies such as on climate change (with ecosystem-based mitigation and adaptation); research and innovation policies (with Nature-Based Solutions); water policies (with Natural Water Retention Measures); and - not least - into nature policies.

Natural Water Retention Measures are multi-functional measures that aim to protect water resources and address water-related challenges by restoring or maintaining ecosystems as well as natural features and characteristics of water bodies using natural means and processes. The main focus of applying NWRM is to enhance the retention capacity of aquifers, soil, and aquatic and water dependent ecosystems with a view to improve their status. The application of NWRM contributes to green infrastructure deployment, improves the quantitative status of water bodies as such, and reduces the vulnerability to floods and droughts.

With a large share of disasters linked to climate and weather conditions, Eco-DRR and the other ecosystem-based approaches have much more in common than they differ in practice. They aim to reduce risk and provide a buffer against hazard impacts while increasing ecosystem and societal resilience to disasters. Differences are mainly related to the type of impacts they address or benefits they may generate. For example, EbA is tailored to weather-related impacts such as floods and storms, and should be planned to address both current and future events - thus taking into account the potential changes in frequency and severity of weather-related events due to climate change. For this reason, EbA also often deals with long-term changes within ecosystems (e.g., habitat fragmentation, species migration, biodiversity loss) and how they impact on their ability to withstand current and future impacts. On the other hand, Eco-DRR considers immediate and medium term impacts (e.g. loss of livelihoods, food and water security) from a broader range of hazards (including also geological and other types of hazards). There is thus a significant overlap between Eco-DRR and EbA [2], and integrating such approaches into governance and development plans may help improving our understanding of risks, while providing an opportunity for faster implementation [42].

3.2. EU initiatives to support and promote Eco-DRR

Investing in risk prevention is key to ensure the capacity for further socio-economic development. It is also more effective than bearing the cost of inaction: for every €1 spent on prevention, €4 or more will be saved on response (source [11,18,19]). In this respect, the EU cohesion policy is key to disaster prevention and management. For the 2014–2020 period, climate change adaptation and risk prevention are included as a single priority in the European Structural Fund, to which 20 Member States have allocated about 28 billion Euros [21], making it the largest EU funding source for this issue. This includes cross-border and transnational investments. In addition, following the horizontal mainstreaming of sustainable development (see above), disaster risk reduction needs to be promoted throughout the ESI Funds' investments, including in transport and health infrastructure, research and innovation, SMEs, etc. During the negotiations on the operational programmes for the Cohesion Fund and European Regional Development Fund, the European Commission stressed that ecosystem-based adaptation should be the preferred option, and promoted the use of green infrastructure measures as a way to translate the sustainable development principle into practice [13]. Figures comparing the allocations to green infrastructure with the previous funding period suggest that this approach led to an increased uptake of green infrastructure measures [18]. The Commission also developed a guide to help the Funds' managing authorities in the implementation [11,12].

Cohesion policy support to risk management is complemented by other EU instruments, such as the Civil Protection Mechanism, the EU Solidarity Fund, Horizon 2020, and the LIFE programme. For nearly 20 years, the European Commission's Directorate General for Civil Protection and Humanitarian Aid Operations has consistently funded Disaster Risk Reduction programmes. In 2016, 9% of the EU's humanitarian funding (ca. 175 million Euros) went to Disaster Risk

Reduction (DRR) activities. Since the 7th Framework Programme and now Horizon 2020, EU research in the field of Disaster Risk and Crisis Management has become more multidisciplinary and has promoted a systemic-risk approach [22]. EU-funded projects have delivered much needed evidence on the complex interactions between the hazard element and the natural and the built environment. In light of this new direction, vulnerability studies, integrated risk assessments and disaster risk management strategies increasingly consider the social, economic, environmental and health dimensions of risk. EU-funded demonstration projects and other instruments are supporting the development and the awareness of ecosystem-based Disaster Risk Reduction, as well as demonstrating their added value in terms of co-benefits for local economies, social cohesion and the broader environment. New research avenues will further address the multi-risk impacts of physical hazards (floods, droughts, forest fires, etc) and the cascading effects of those hazards in order to integrate this information into the overall assessments.

The EU also contributes to research and knowledge-building for ecosystem-based disaster risk reduction, through integrating the concept of ecosystem-based approaches in its R&I agenda (e.g., the EU R&I agenda for Nature-Based Solutions, [28]), and through initiatives such as the Disaster Risk Management Knowledge Centre (DRMKC) to pool the knowledge and networks on Eco-DRR and make those research results accessible. The DRMKC aims at enhancing the knowledge base through analytical and networking activities and providing a repository of relevant research and projects and new initiatives to deepen knowledge and support policy-making. OPPLA is an open platform for collaboration between science, practice and policy communities on natural capital, ecosystems services and Nature-Based Solutions, where the ouputs of research are made accessible to end-users. Other instruments that support research and knowledge for Eco-DRR in the EU also include the EU Mapping and Assessment of Ecosystems and their Services (MAES) framework. The MAES action aims to provide a knowledge base on ecosystems and their services in Europe. It underpins the achievement of all 6 targets of the EU Biodiversity Strategy to 2020 and is relevant to a number of other EU sectoral policies such as agriculture, forestry, climate change, maritime affairs and fisheries, and cohesion. Impact assessment frameworks and guidance tools have also been developed such as the EU science-policy-society mechanism EKLIPSE [38] to guide local decision-makers and practitioners in planning, monitoring and evaluating the vulnerability of ecosystem services to natural hazards as well as the cost and benefits of different ecosystem-based risk mitigation options. The European Climate Adaptation Platform (Climate-ADAPT), hosted by the European Environment Agency, aims to support Europe in adapting to climate change. This initiative helps users to access and share information on the expected climate change in Europe, current and future vulnerability of regions and sectors, national and transnational adaptation strategies, adaptation case studies and potential adaptation options, and tools that support adaptation planning at different levels. Climate-ADAPT includes information and guidance on policies, methodologies and good practices, including ecosystem/biodiversity based adaptation strategies. The European Commission aims at improving the coherence and enabling the interoperability within existing information-sharing mechanisms and underlying data centres.

4. From policies to practice: strengthening capacities for ecosystem-based disaster risk management

4.1. Demonstrating the effectiveness of Eco-DRR approaches

The policy frameworks and funding instruments described in the previous sections of this paper have generated a wealth of practical experiences and lessons learned in the implementation of ecosystem-based approaches. Mc Alistair et al. [33], provide an overview of selected case studies from a variety of sectors and European countries. Nonetheless, in this section we will describe in detail three case studies at different governance levels, selected to illustrate how EU policies and funding instruments can leverage investment and enhance disaster and climate resilience, the protection/restoration of ecosystems, and generate multiple benefits under different circumstances. To ensure effective replicability, the EU project EKLIPSE, which aims at facilitating linkages between science, policy and society, has developed an impact evaluation framework [38] to guide demonstration projects in the design, development, implementation and assessment of Nature-Based Solutions for climate resilience in urban areas. Such assessment framework can be applied across projects in several European regions so that their outputs can be compared.

4.1.1. Ecosystem-based approaches for urban resilience

The Ljubljana Urban Region has seen a rapid urbanisation in the last 25 years that, coupled with fragmented governance, has resulted in urban sprawl and urbanisation of areas exposed to risk of floods. Water management and frequent flooding – expected to be exacerbated by climate change – are presenting a challenge to the region, compounded by fragmented governance in the water sector, poor maintenance of flood protecting infrastructure and river beds, and weak building standards and regulations.

The city of Ljubljana, Slovenia has implemented over the years numerous green initiatives to regenerate the city, mitigate climate change and preserve ecosystems, while at the same time improving quality of life and boosting tourism that have earned the city the title of European Green Capital of 2016. The measures implemented can be grouped into three broad areas of intervention:

- Establishment of an "urban ecological zone" within the city centre, closing it to motorised traffic, and gradually expanding it. Sustainable mobility, such as electric cars and biking has been promoted, new bridges built to shorten distances and connect better different areas of the city. This has created a high-quality public space, and shortened routes for pedestrians and cyclists.
- Increasing green areas in and around the city: to date, almost three fourth of the city's surface area is green areas (and 16.5% is Natura 2000 areas). Almost 81% of the green areas are on the outskirts of the city (contiguous freshwater, forest and agricultural areas), connected to the historical centre via green wedges and riparian corridors. Furthermore, between 2009 and 2016 Ljubljana created 90 ha of new public green areas in the city on former brownfield/degraded lands.
- Restoration of the river Ljubljanica, including through planting new vegetation, improving the microclimate around the river and providing shade, thus contributing to both reducing the risk of floods and mitigating the impacts of heat waves. Moreover, with funding from LIFE+, the connectivity between Natura 2000 sites was improved. Barriers to fish migration were removed, degraded habitats restored, the water management infrastructure improved, including by putting in place a water monitoring system. The rehabilitation of the river is a good example of linking green space with urban rehabilitation.

While many of the measures have been planned separately at different times, they have been implemented in a coordinated manner, enabling synergies between them. For example, the refurbishment of the banks and bridges of the river Ljubljanica is an example of linking green spaces with urban rehabilitation. The LIFE project Ljubljanica Connects has been designed to improve the connectivity between Natura 2000 sites. Started in 2012, the project aims to remove barriers to fish migration, enhance and restore habitats, improve the water management infrastructure, and put in place a water monitoring system. In this framework, green areas have an important role in enabling ecosystem functions, such as climate change mitigation and improving health and recreation for residents. Benefits of the

implemented action include cooling effects in urban areas and flood prevention. In addition, European Union funding instruments, such as LIFE and the 7th Framework Programme, contributed to mobilising financial resources and establishing a network with various stakeholders, thus facilitating the implementation of the actions.

4.1.2. Eco-DRR at river-basin level for flood protection

The Emscher valley, in the Ruhr region of Germany, witnessed a radical transformation of its landscape over the last century. Due to subsidence caused by mining, it was impossible to build an underground sewer system. Therefore, the Emscher and its tributaries were used to transport the wastewater together with rainwater on the surface. This resulted in extreme fluctuations in the amounts of water discharged. With the decline in the mining industry, traditional heavy industry gave way to the services and high-tech industries.

In the 1990s restoration of the 82 km stretch of river in a catchment of 865 square kilometres began, gradually creating the New Emscher Valley taking into account the effects of climate change [30]. According to long-range climate projections, the Emscher area will see more frequent extreme winds and storms and recurring events of extreme rainfall. These climatic changes will have socio-economic impacts and affect the regions' productivity and competitiveness. Rather than choosing a traditional approach to climate resilience, making use of grey engineering with technical solutions such as building higher dikes and bigger sewers or enhancement of pumping stations, the Emschergenossenschaft, the water management association responsible for Emscher, chose a more flexible nature-based solution. By coupling the channelling of the wastewater from the Emscher and its tributaries into closed sewers with the revitalisation of the rivers, the water cycle is now strengthened, and the water buffering and cooling effects provided by nature's ecosystem services are harnessed.

The restoration project cost 4.5 billion Euros from its inception to its expected completion in 2020, making the Emscher conversion one of Europe's biggest infrastructure projects. Major sources of funding came from the State Government of North-Rhine Westphalia and EU structural funds. However, the project is also a good example of integration of multiple sources of funding, instruments and resources to achieve a common objective: complementary funding sources included the 7th Framework Programme, Horizon 2020 and LIFE+, as well as national and municipal funding, and contributions from private parties, local businesses and NGOs. The Emscher revitalisation has already generated thousands of jobs, in addition to improving the quality of life and work in the area and improving the Ruhr area's attractiveness [29]. Despite the large investment, the water management association estimates that a traditional infrastructure approach would have been significantly more expensive, while not achieving such a high level of resilience to increases in rainfall. The valley now includes cooling green spaces, areas for flood control, recreation areas and a habitat network, therefore enhancing quality of life in the Ruhr metropolitan area today and making it more resilient to the impacts of climate change. Taking an integrated and holistic approach, the Emscher Valley has an improved capacity as carbon sink, a more favourable microclimate, reduced flood risks in case of heavy rainfall events and a more balanced water cycle in times of dry summer periods.

4.1.3. Promoting cross-border collaboration for enhanced resilience to floods

About 80% of Danube's wetlands have been lost in the past century due to habitat conversion, while the construction of dikes reduced the size of floodplains. In addition gravel extraction, dredging and dams have contributed to river bed erosion. The Danube basin is prone to floods: in 2005, a flood killed 34 people, displaced 2000 people, inundated 690 km^2 and caused 396 million Euros in damages in Hungary, Romania, Bulgaria and Moldova [4]. And the impacts of climate change in the region are expected to lead to an increase in frequency and intensity of droughts and extreme rainfall, leading to high-river flows [5].

In 2000, the governments of Bulgaria, Romania, Ukraine and Moldova signed the Lower Danube Green Corridor Agreement to restore 2323 km of floodplain and to establish a green corridor along the entire length of the Lower Danube River (~1000 km). The aim of the project is to reduce the risk of major flooding in areas with human settlements, restore and protect biodiversity, improve water quality and enhance local livelihoods. Once fully restored, these lands will be of similar scale as the area inundated in the 2005 and 2006 floods.

The Green Infrastructure along the river is protected and restored, e.g., through natural wetlands, and the river is reconnected to its natural flooding areas. In addition, co-benefits are created both for local economies (e.g., through fisheries and tourism) and restoring an ecological corridor for migrating species along the river. As of 2012, 600 km^2 of floodplain has been restored or is undergoing restoration. Most flood plain restorations have been achieved by removing sections of dykes. The benefits of restoration were already observed in 2013, when the lower Danube did not experience any flooding, even though the water level was well above the average. EU Directives, such as the Birds and Habitats Directive and the Water Framework Directive, were instrumental in the implementation of Natura 2000 in Romania and Bulgaria; while the former contributed to increasing the area under protection, the latter opened new opportunities to restore lateral connectivity.

The total costs have been estimated at 183 million Euros, while the economic benefits through the avoidance of damage due to floods are much larger. In addition, the expected earnings through ecosystem services (e.g., fisheries, tourism) are about 85.6 million Euros per year. Each ha of restored floodplain is estimated to provide 500 Euros per year in ecosystem services, helping to diversify livelihoods [5].

4.2. Enablers for mainstreaming Eco-DRR in the EU

4.2.1. Developing technical and scientific references for Eco-DRR

Although the concept of Eco-DRR is now internationally recognised with a growing body of knowledge and practice [3], Eco-DRR approaches are not yet fully mainstreamed into national development policies and programmes and need to be stimulated and encouraged [35]. Demonstrating the resilience and cost-effectiveness of Eco-DRR measures to create new knowledge and build capacities in local communities and authorities is required. This can only be achieved if methods, protocols, standards, performance indicators and guidance for the way to compare Eco-DRR and other traditional solutions are developed. For instance, the EU project FAST (Foreshore Assessment using Space Technology) developed down-stream services for the European Earth Observation Programme Copernicus to support cost-effective, nature-based shoreline protection against flooding and erosion. Results showed that healthy marsh reduces the need for seadike elevation as the extent and depth of flooded marsh area was significantly reduced in presence of vegetation. According to model simulations using a normative storm with waves' height up to 6 m and sea surface level of 4 m, inundated surface without vegetation approximated 340 ha, and only 193 ha with vegetation [34]. In implementing Eco-DRR solutions, there is a need to explore all the direct and indirect benefits brought by these options (short to long-term) and assess their added value while recognizing that certain ecosystems, e.g. wetlands, can be managed to address multiple hazards (floods, drought, fire, etc.). As a further contribution to implementing the EU Sendai Action Plan, the European Commission is committed to produce an assessment framework and guidance for developing Green Infrastructure in cities, while assessing the opportunities for a Trans-European Network for Green Infrastructure.

4.2.2. Engaging with multiple actors / partners in designing, researching and implementing ecosystem-based approaches for disaster risk reduction

The Partnership for Environment and Disaster Risk Reduction (PEDRR) is a global alliance of 22 member organizations of UN, civil

society and specialized agencies, which actively supported Member States and country representatives throughout the negotiations of the SFDRR. Since 2008, PEDRR has facilitated implementation, knowledge sharing and collective actions related to ecosystem-based approaches to disaster risk reduction and climate change adaptation (Eco-DRR/CCA). Through the SFDRR, there is new opportunity to raise global actions and scale up investments in Eco-DRR/CCA.

The Sendai Framework for Disaster Risk Reduction 2015–2030 encourages the setting up of national and regional platforms for DRR. These platforms can help define national policy on disaster risk reduction and management. The Bulgarian national platform, for example, brings together representatives of all ministries and agencies, the Bulgarian Academy of Sciences, the National Association of Municipalities, the Bulgarian Red Cross, the Chamber of Commerce and the Bulgarian Industry Association. Such a broad coalition of stakeholders helped to define a national disaster risk reduction strategy [14].

Initiatives addressing disaster risk management on a supra-national scale exist, but these remain limited to a number of EU macro-regional strategies (Danube, Baltic, Alpine, Adriatic) or hazard-specific cooperative initiatives (e.g. Nordic Forum for Risk Analysis). The EU-FP7 ENHANCE project focuses on different multi-sector partnerships and their value for DRR, demonstrating that partnerships of multiple stakeholders from different sectors have added benefits that a purely government-centred approach cannot deliver. Partnerships between policy-makers, scientists and practitioners are also encouraged via the EU Disaster Risk Management Knowledge Centre [36]. Another example of such a partnership is the Community of Users for security research, which also covers disaster-resilient societies [37].

4.2.3. Developing financial support and markets for Eco-DRR approaches

It is necessary to identify the types of financial, social, economic, political incentives needed to improve ecosystem-based disaster risk management. For instance, taking the case of a river basin, an Eco-DRR approach will help link the urban-rural interface, as well as upstream and downstream. The FP7 project ENHANCE analysed a variety of economic instruments for disaster risk reduction and came to the conclusion that some may have, inadvertently, adverse effects on the environment (by encouraging more economic activity in sensitive areas, for example), while others can contribute to a holistic approach to DRR including environmental and ecosystem considerations. Objective 5 of the European Structural and Investment Funds addresses both risk prevention and climate change adaptation, inviting EU countries to reflect on developing common investment projects.

The Commission will also continue to support the implementation of ecosystem-based approaches to disaster risk reduction through development assistance in at least 20 most vulnerable countries, mainly Least Developed Countries (LDCs) and Small Islands Developing States (SIDS). Disseminating lessons learned from successful implementation and scientific evidence on Eco-DRR effectiveness, engaging multiple stakeholders will be ensured by EU R&I projects and other EU funds programmes demonstrating the added value of Nature-Based Solutions and other ecosystem-based approaches. In addition to promoting a better understanding of the long-term efficacy of Eco-DRR/CCA solutions, research is also needed in assessing the required management to maintain such solutions over time due to the inherent cyclic nature of their living components.

5. Conclusion

Since 2005, natural disasters have cost the EU close to 100 billion Euros [19]. Ecosystem-based approaches are among the many activities promoted by the European Commission to support risk prevention and increase resilience to disasters. Eco-DRR has the potential to deliver on several of the current policy priorities: by combining climate benefits (both for adaptation and mitigation), environmental improvements (restoration of landscape, biodiversity, etc.) and risk reduction (primarily by reducing the vulnerability and exposure of man-made assets, e.g. floodplains protecting infrastructure). At the global scale, ecosystem-based approaches can help deliver on our commitments under the Paris Agreement, the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction. At EU level, an integrated DRR policy agenda supported by the EU Action Plan on the Sendai Framework for Disaster Risk Reduction will foster new initiatives and actions to address the shortage of scientific evidence on implementing Eco-DRR approaches and engage local community members.

The design and planning of Eco-DRR should increasingly consider the social dimension of risk management so that local authorities can make better-informed choices in a post-disaster situation. Yet, Eco-DRR and other ecosystem-based approaches offer a strong opportunity to address multiple societal challenges simultaneously to an extent that say the use of grey infrastructure for disaster risk management cannot deliver. While the evidence on the social, economic, cultural and ecological benefits offered by such solutions is growing and many successful examples are becoming available in the European context and outside, the upscaling and take up of Eco-DRR solutions by authorities is still limited [44]. This commonly experienced ‘Implementation Gap’ should be addressed through inclusive partnerships between public authorities, private sector, academic institutions and civil society to implement disaster risk reduction measures that foster innovation, for example combining the use of hard (grey) and soft (green) infrastructure. Robust EU-wide evidence and adequate proof-of-concept for the upscaling and replication of ecosystem-based approaches can be provided via large-scale demonstration projects and will ensure their wider deployment [15,28].

Disclaimer

All views expressed in this article are entirely the authors' own. They do not reflect the position of the EU institutions and do not, in any way, engage any of them.

References

[1] J. Birkmann, K. von Teichman, Integrating disaster risk reduction and climate change adaptation: key challenges – scales, knowledge, and norms, Sustain. Sci. 5 (2010) 171–184.
[2] N. Doswald, M. Estrella, Promoting Ecosystems for Disaster Risk Reduction and Climate Change Adaptation: opportunities for integration, UNEP, Geneva, 2015〈http://www.unep.org/disastersandconflicts/portals/155/publications/EcoDRR_Discussion_paper_web.pdf〉 (Accessed May 2017).
[3] N. Doswald, M. Osti, Ecosystem-based approaches to adaptation and mitigation – good practice examples and lessons learned in Europe, BfN Skripten 306, 2013.
[4] Orieta Hulea, Suzanne Ebert, David Strobel, Floodplain restoration along the Lower Danube: a climate change adaptation case study, Global Risks, Challenges and Decisions, IOP Conference Series: Earth and Environmental Science 6, 2009.
[5] Hulea Eber, Suzanne, David Orieta, Strobel, Floodplain restoration along the lower Danube: a climate change adaptation case study, Clim. Dev. 1 (3) (2009) 212–219.
[6] M. Estrella, N. Saalismaa, Ecosystem-based disaster risk reduction (Eco-DRR): an overview, in: F. Renaud, K. Sudmeier-Rieux, M. Estrella (Eds.), The Role of Ecosystem Management in Disaster Risk Reduction, UNU Press, Tokyo, 2013.
[7] European Commission, EU strategy for supporting disaster risk reduction in developing countries. COM(2009)84final, 2009.
[8] European Commission, A community approach on the prevention of natural and man-made disasters. COM(2009)82 final, 2009.
[9] European Commission, Commission staff working document: Risk assessment and mapping guidelines for disaster management. Brussels: SEC(2010) 1626 final, 2010.
[10] European Commission, EU approach to resilience: learning from food security crises. COM(2012)0586 final, 2012.
[11] European Commission, 2013. Guide to multi-benefit cohesion policy investments in nature and green infrastructure. 〈http://ec.europa.eu/regional_policy/en/information/publications/guides/2013/guide-to-multi-benefit-cohesion-policy-investments-in-nature-and-green-infrastructure〉.
[12] European Commission, An EU Strategy on adaptation to climate change. COM (2013) 216 final, 2013.
[13] European Commission, Draft thematic guidance fiche for desk officers. climate change adaptation, risk prevention and management, 2014. 〈http://ec.europa.eu/regional_policy/en/information/legislation/guidance/〉.
[14] European Commission, 2015-2016 Programme for peer reviews in the framework of

EU cooperation on civil protection and disaster risk management. Peer Review Bulgaria Report, 2015. Available at: ⟨http://www.falck.nl/nl/peerreviews/publications/Documents/Bulgaria%202015%20peer%20review%20report%20-%20EN.pdf⟩.
[15] European Commission, Horizon 2020 TOPIC: 'SC5-08-2017: Large-scale demonstrators on nature-based solutions for hydro-meteorological risk reduction' ⟨http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/sc5-08-2017.html⟩; published 14 October 2015, last last accessed 15 December 2017.
[16] European Commission, Next steps for a sustainable European future European action for sustainability. COM(2016) 739 final, 2016.
[17] European Commission, Action plan on the sendai framework for disaster risk reduction 2015-2030: A disaster risk-informed approach for all EU policies. SWD (2016) 205 final/2, 2016.
[18] European Commission. Mainstreaming the environment in cohesion policy in 2014–2020. Report of the European Network of Environmental Authorities – Managing Authorities (ENEA-MA) working group, 2016. ⟨http://ec.europa.eu/environment/integration/pdf/enea/ENEAMA_eport_April_2017_24.pdf⟩.
[19] European Commission. Funding opportunities to support disaster risk prevention in the cohesion policy2014-2020 period, 2016. Available at ⟨http://ec.europa.eu/regional_policy/sources/docgener/informat/factsheet_disaster_risk_prevention_03.pdf⟩.
[20] European Commission, Communication from the Commission to the European Parliament, the Council and the Committee of the Regions. Strengthening EU Disaster Management: rescEU Solidarity with Responsibility Solidarity with Responsibility. COM/2017/0773. Brussels, 23 November 2017.
[21] European Commission, European Structural and Investment Funds (ESI Funds) - explore our data, 2017.⟨https://cohesiondata.ec.europa.eu/⟩.
[22] European Commission, A Community of Users on Secure, Safe, and Resilient Societies (CoU): Mapping EU Policies and FP7 Research for Enhancing Partnerships in H2020. Available at ⟨https://www.cbrn-networkofexcellence.org/filter-results-3/publication⟩ (Accessed 4 December 2017).
[23] European Environment Agency, The European Environment - State and Outlook 2015: Synthesis Report, European Environment Agency, Copenhagen, Denmark, 2015.
[24] European Environment Agency, Flood risks and environmental vulnerability - Exploring the synergies between floodplain restoration, water policies and thematic policies. EEA Report No 1/2016. Luxembourg, 2016. doi:10.2800/039463.
[25] European Environment Agency, Climate change, impacts and vulnerability in Europe 2016. EEA Report No 1/2017. Copenhagen, Denmark, 2017. doi:10.2800/534806.
[26] European Union, Consolidated version of the treaty on the functioning of the European Union. OJ C 326, Article 11. Published on 26.10.2012.
[27] European Union EU Regulation No 1303/2013 of the European Parliament and of the Council of 17 December 2013. Article 8, 2013.
[28] N. Faivre, M. Fritz, T. Freitas, B. de Boissezon, S. Vandewoestijne, Nature-Based Solutions in the EU: innovating with nature to address social, economic and environmental challenges, Environ. Res. 159 (2017) 509–518, http://dx.doi.org/10.1016/j.envres.2017.08.032.
[29] D. Gruehn, Regional planning and projects in the Ruhr region (Germany), in: M. Yokohari, A. Murakami, Y. Hara, K. Tsuchiya (Eds.), Sustainable Landscape Planning in Selected Urban Regions. Science for Sustainable Societies. Springer, Tokyo, 2017.
[30] N. Herbke, B. Pielen, J. Ward, R. Kraemer, Urban Water Management Case Study: Emscher Region, Ecologic - Institute for International and European Environmental Policy, Berlin, 2006 (Accessed 10 December 2017), ⟨http://ecologic.eu/download/vortrag/2006/herbke_milan_emscher.pdf⟩.
[31] IPPC, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation'. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2012.
[32] L. Mazza, G. Bennett, L. De Nocker, S. Gantioler, L. Losarcos, C. Margerison, T. Kaphengst, A. McConville, M. Rayment, P. ten Brink, G. Tucker, R. van Diggelen, Green Infrastructure Implementation and Efficiency, Institute for European Environmental Policy, Brussels and London, 2011 (Final report for the European Commission, DG Environment on Contract ENV.B.2/SER/2010/0059).
[33] Alistair McVittie, Lorna Cole, Anita Wreford, Alessandra Sgobbi, Beatriz Yordi, Ecosystem-based solutions for disaster risk reduction: lessons from European applications of ecosystem-based adaptation measures, Int. J. Disaster Risk Reduct (2017) (in this issue).
[34] E.P. Morris, J. Gomez-Enri, D. Van der Wal, Copernicus downstream service supports nature-based flood defense: use of sentinel Earth Observation Satellites for coastal needs, Sea Tech. 56 (2015) 23–26.
[35] R. Munang, I. Thiaw, K. Averson, J. Liu, Z. Han, The role of ecosystems services in climate change adaptation and disaster risk reduction, Curr. Opin. Environ. Sustain. 5 (2013) 47–52.
[36] K. Poljanšek, M. Marín Ferrer, T. De Groeve, I. Clark (Eds.), Science for Disaster Risk Management. 2017: Knowing Better and Losing Less, Publications Office of the European Union, Luxembourg, 2017.
[37] Quevauviller, P. 2014. A community of users on secure, safe and resilient societies (CoU). Mapping EU policies and FP7 research for enhancing partnerships in H2020, Brussels, Belgium. Available at ⟨https://ec.europa.eu/home-affairs/sites/homeaffairs/files/what-we-do/policies/industry-for-security/docs/dg_home_cou_mapping_en.pdf⟩.
[38] C.M. Raymond, P. Berry, M. Breil, M.R. Nita, N. Kabisch, M. de Bel, V. Enzi, N. Frantzeskaki, D. Geneletti, M. Cardinaletti, L. Lovinger, C. Basnou, A. Monteiro, H. Robrecht, G. Sgrigna, L. Munari, C. Calfapietra, An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects (Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas, Centre for Ecology & Hydrology, Wallingford, United Kingdom, 2017.
[39] F.G. Renaud, K. Sudmeier-Rieux, M. Estrella, The Role of Ecosystems in Disaster Risk Reduction, United Nations University Press, Tokyo, 2013 (Eds).
[40] K. Sudmeier-Rieux, Ecosystem approach to disaster risk reduction: basic concepts and recommendations to governments, with a special focus on Europe. Council of Europe, European and Mediterranean Major Hazards Agreement (EUR-OPA), 2013.
[41] United Nations, Sendai Framework for Disaster Risk Reduction 2015–2030, UNISDR, Geneva, 2015.
[42] T. Salvaterra, K. Allenbach, P. Hobson, P.L. Ibisch, H. Korn, J. Mysiak, F. Renaud, M. Pulquério, Exploring the potential of ecosystem-based approaches - Ecosystem-based Adaptation and Ecosytem-based Disaster Risk Reduction. Policy brief with proceedings from PLACARD session convened as part of the 4th Adaptation Futures Conference, 10-13 May, Rotterdam, The Netherlands, 2016.
[43] Secretariat of the Convention on Biological Diversity, Year in Review 2009. Montreal, 2010, 42 pages.
[44] V. Lo, Synthesis report on experiences with ecosystem-based approaches to climate change adaptation and disaster risk reduction. Technical Series No.85. Secretariat of the Convention on Biological Diversity, Montreal, 2016, 106 pages.